77 Rec'd PCT/PTO 10 DEC 2001

| FORM PTO-1390 (REV 5-93) | U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE | ATTORNEY DOCKET NO. 108347-00014 |
|---|---|---|
| TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371 | | DATE: December 10, 2001 |
| | | U.S. APPLN. NO. (IF KNOWN, SEE 37 C.F.R. 1.5) 09/926734 |
| INTERNATIONAL APPLICATION NO. PCT/GB00/01903 | INTERNATIONAL FILING DATE 18 May 2000 | PRIORITY DATE CLAIMED 9 June 1999 |

TITLE OF INVENTION: HOLOGRAPHIC DISPLAYS

APPLICANT(S) FOR DO/EO/US: Douglas PAYNE (Malvern, Warwickshire, United Kingdom); and Christopher W. SLINGER (Malvern, Warwickshire, United Kingdom)

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371. (THE BASIC FILING FEE IS ATTACHED)
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures [35 U.S.C. 371(f)] at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper demand for International Preliminary Amendment was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed [35 U.S.C. 371(c)(2)]
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English [35 U.S.C. 371(c)(2)].
7. ☐ Amendments to the claims of the International Application under PCT Article 19 [35 U.S.C. 371(c)(3)]
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 [35 U.S.C. 371(c)(3)].
9. ☐ An oath or declaration of the inventor(s) [35 U.S.C. 371(c)(4)].
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 [35 U.S.C. 371(c)(5)].

Items 11 - 16 below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: CHECK NO. 330859; Formal Drawings (Figs. 1-8; 6 sheet); Front Page of Published Application; Copy of Form PCT/ISA/210; Copy of Form PCT/IPEA/416; Copy of Form PCT/IPEA/409; Copy of a Change of Name Deed; Copy of Letter to WIPO dated June 15, 2001 enclosing an Assignment

JC13 Rec'd PCT/PTO 10 DEC 2001

| U.S. APPLN. NO. (IF KNOWN, SEE 37 C.F.R. 1.5) 09/926734 | INTERNATIONAL APPLICATION NO. PCT/GB00/01903 | ATTORNEY DOCKET NO. 108347-00014<br>DATE: December 10, 2001 |
|---|---|---|

| | | | | CALCULATIONS | PTO USE ONLY |
|---|---|---|---|---|---|
| 17. ☒ The following fees are submitted:<br>**Basic National Fee [37 C.F.R. 1.492(a)(1)-(5)]:**<br>Search Report has been prepared by the EPO or JPO............$890.00<br>International preliminary examination fee paid to USPTO (37 C.F.R. 1.482)..........................................$710.00<br>No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO [37 C.F.R. 1.445(a)(2)]....................................$740.00<br>Neither international preliminary examination fee (37 C.F.R. 1.482) or international search fee [37 C.F.R. 1.445(a)(2)] paid to USPTO.....................$1,040.00<br>International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4).......................................$ 100.00 | | | | | |
| **ENTER APPROPRIATE BASIC FEE AMOUNT =** | | | | $ 890.00 | |
| Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date [37 C.F.R. 1.492(e)]. | | | | | |
| Claims | Number Filed | Number Extra | Rate | | |
| Total Claims | 11 - 20 = | 0 | X $ 18.00 | | |
| Independent Claims | 3 - 3 = | 0 | X $ 84.00 | | |
| Multiple dependent claim(s) (if applicable) | | | + $280.00 | | |
| **TOTAL OF ABOVE CALCULATIONS =** | | | | $ 890.00 | |
| Reduction by one-half for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28). - | | | | | |
| **SUBTOTAL =** | | | | $ 890.00 | |
| Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date [37 C.F.R. 1.492(f)]. + | | | | | |
| **TOTAL NATIONAL FEE =** | | | | $ 890.00 | |
| Fee for recording the enclosed assignment [37 C.F.R. 1.21(h)]. The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property + | | | | | |
| **TOTAL FEES ENCLOSED =** | | | | $ 890.00 | |
| | | | | Amount to be refunded | $ |
| | | | | Charged | $ |

a. ☒ A check in the amount of $890.00 to cover the above fees is enclosed.
b. ☐ Please charge my Deposit Account No. 01-2300 in the amount of $ to cover the above fee. A duplicate copy of this sheet is enclosed.
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 01-2300.

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive [37 C.F.R. 1.137(a) or (b)] must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:
**Customer No. 004372**
**Arent Fox Kintner Plotkin & Kahn**
**1050 Connecticut Avenue, N.W., Suite 400**
**Washington, D.C. 20036-5339**
**Tel: (202) 857-6000 Fax: (202) 638-4810**

**Douglas H. Goldhush**
Reg. No. 33,125

09/926734

JC13 Rec'd PCT/PTO 10 DEC 2001

**PATENT APPLICATION**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

PAYNE et al

Group Art Unit: Not yet assigned

International Application No.: PCT/GB00/01903

Examiner: Not yet assigned

Filed: December 10, 2001

Attorney Dkt. No.: 108347-00014

For: HOLOGRAPHIC DISPLAYS

**PRELIMINARY AMENDMENT**

Commissioner for Patents
Washington, D.C. 20231

December 10, 2001

Sir:

Prior to calculation of the filing fees and initial examination of the application, please amend the above-identified application as follows:

**IN THE CLAIMS**:

Please amend claims 4, 6, and 8, as amended in the International Preliminary Examination Report dated June 19, 2001, as follows. A copy of the marked up original claims is attached to this response showing the changes as set forth in amended 37 CFR 1.121.

4. (Amended) A display according to claim 1, wherein the light guiding means comprises means disposed at the EASLM projection surface, or between the EASLM and the EASLM projection surface, for causing the apparent diverging light illumination of the EASLM images to be redirected to appear to be a plane wave or other wavefront illumination.

6. (Amended) A display according to claim 1, wherein the light source used to illuminate the EASLM comprises a single light source, or a plurality of light sources.

8. (Amended) A display according to claim 1, wherein baffles are positioned in an intermediate image plane so that light associated with the d.c. spot and conjugate image is blocked.

## REMARKS

Claims 1-11 are pending in this application. By this Amendment, claims 4, 6 and 8, as amended in the International Preliminary Examination Report dated June 19, 2001, are amended to correct the multiple dependencies thereof and to place this application into better condition for examination. No new matter has been added.

In the event that there are any fees due with respect to the filing of this paper, please charge Deposit Account No. 01-2300.

Respectfully submitted,

Douglas H. Goldhush
Registration No. 33,125

**Customer No. 004372**
ARENT FOX KINTNER PLOTKIN & KAHN, PLLC
1050 Connecticut Avenue, N.W.,
Suite 400
Washington, D.C. 20036-5339
Tel: (202) 857-6000
Fax: (202) 638-4810
DHG:scc

Enclosures: Marked-up Copy of Amended Claims 4, 6 and 8

**MARKED-UP COPY OF AMENDED CLAIMS 4, 6 AND 8**
**ATTY. DOCKET NO. 108347-00014**

4. (Amended) A display according to [any one of the preceding claims] claim 1, wherein the light guiding means comprises means disposed at the EASLM projection surface, or between the EASLM and the EASLM projection surface, for causing the apparent diverging light illumination of the EASLM images to be redirected to appear to be a plane wave or other wavefront illumination.

6. (Amended) A display according to [any one of the preceding claims] claim 1, wherein the light source used to illuminate the EASLM comprises a single light source, or a plurality of light sources.

8. (Amended) A display according to [any one of the preceding claims] claim 1, wherein baffles are positioned in an intermediate image plane so that light associated with the d.c. spot and conjugate image is blocked.

09/926734
JC13 Rec'd PCT/PTO 10 DEC 2001

6/parts



# Holographic Displays

The present invention relates to holographic displays and in particular to holographic displays which use an electrically addressable spatial light modulator to generate modulated light for projection onto an optically addressable spatial light modulator.

It is well known that a three-dimensional image may be presented by forming an interference pattern or hologram on a planer surface. The three-dimensional image is visible when the hologram is appropriately illuminated. Recently, interest has grown in so-called computer generated holograms (CGHs) which offer the possibility of displaying high quality images, which need not be based upon real objects, with appropriate depth cues and without the need for viewing goggles. Interest is perhaps most intense in the medical and design fields where the need for realistic visualisation techniques is great.

Typically, a computer generated hologram involves the generation of a matrix of data values (each data value corresponding to a light transmission level) which simulates the hologram which, might otherwise be formed on a real planer surface. The matrix is applied to an Electrically Addressable Spatial Light Modulator (EASLM) which may be, for example, a two-dimensional array of liquid crystal elements or of acousto-optic modulators. Coherent light is directed onto the EASLM using for example a laser such that the resulting output, either reflected from the EASLM or transmitted through the EASLM, is a modulated light pattern.

In order to produce a three-dimensional image of usable size and viewing angle, the EASLM typically has to have a large number of pixels, e.g. $10^{10}$. In addition, the pixels of the EASLM must be positioned relative to one another with a high degree of accuracy. The device must also be capable of modulating coherent light, e.g. produced by a laser. These requirements are extremely demanding and expensive to achieve in practice.

An alternative approach is presented in GB2330471A and is illustrated schematically in Figure 1. This document describes a holographic display technique, which is referred to

as Active Tiling™, and involves the use of a relatively small EASLM 1 in combination with a relatively large Optically Addressable Spatial Light Modulator (OASLM) 2. The holographic matrix is subdivided into a set of sub-holograms, with the data for each sub-hologram being passed in turn to the EASLM 1. The EASLM 1 is illuminated from one side with incoherent light 3. The OASLM 2 comprises a sheet of bistable liquid crystal (in one example the liquid crystal is a ferroelectric liquid crystal) which is switched from a first to a second state by incident light. Guide optics 4, disposed between the EASLM 1 and the OASLM 2, cause the output of the EASLM 1 (i.e. light transmitted through the EASLM 1) to be stepped across the surface of the OASLM 2. The bistable nature of the OASLM liquid crystal means that the portion or "tile" 5 of the OASLM 2 onto which a sub-holographic image is projected, remembers that image until such time as the OASLM is reset by the application of an electrical voltage. It will be appreciated that, providing a reset voltage is applied only at the end of a complete scan, immediately prior to reset the OASLM 2 will have "stored" in it a replica of the complete holographic matrix. The holographic display also typically comprises a large output lens, although this is not shown in Figure 1.

The need for an OASLM 2 in the display of GB2330471A is demanding and expensive to implement in practice. Furthermore, the need for the OASLM to have memory and for it to be reset at the end of each scan, requiring as it does the use of surface electrodes, adds complexity and therefore yet more expense to the holographic display.

It is an object of the present invention to overcome or at least mitigate the above noted disadvantages. This and other objects are achieved at least in part by providing a holographic display having an EASLM which is illuminated with coherent light and which is used to display sub-holographic images.

According to a first aspect of the present invention there is provided a holographic display comprising:

a source of coherent light;

an Electrically Addressable Spatial Light Modulator (EASLM) in the path of the light source and arranged in use to be driven successively by a set of sub-holograms which together correspond to a holographic image; and

light guiding means arranged to guide light output from the EASLM such that the sub-holograms are displayed successively in respective tiled regions of an EASLM projection surface.

The present invention takes advantage of the "memory" which is inherent in the human eye. Providing that the light output corresponding to each sub-hologram is of sufficient amplitude, an observer will remember that sub-hologram at least for the time it takes to display the entire set of sub-holograms making up the sub-holographic image. There is thus no need for an OASLM.

In certain embodiments of the invention, the sub-hologram images appear at the projection surface as though they are illuminated with a plane wave

Preferably, said light guiding means comprises replicating optics arranged in use to replicate the light output from the EASLM so as to provide multiple images. More preferably, the light guiding means comprises an array of electronically controlled baffles or shutters disposed between the replicating optics and said EASLM projection surface, said baffles/shutters being controlled such that only that baffle/shutter, which is aligned with a tiled region of the EASLM projection surface associated with a given sub-hologram, is open when the EASLM is being driven by that sub-hologram.

Preferably, the light guiding means comprises means disposed at the EASLM projection surface, or between the EASLM and the EASLM projection surface, for causing diverging light to be redirected to provide a plane wave. More preferably, this means comprises an array of lenses or a holographic redirector disposed at or near the EASLM projection surface.

The sub-hologram images on the EASLM projection surface may produce discrete sets of wavefronts which converge on object points.

The light source used to illuminate the EASLM may comprise a single light source, or a plurality of light sources. For example, the light source may be an array of light sources disposed behind the replicating optics such that the EASLM is illuminated at the desired

angle of incidence and with a wavefront of the desired form (e.g. plane/converging/diverging).

Preferably, the angle of incidence of the light upon the EASLM depends upon the spatial position, within the hologram, of a sub-hologram currently being displayed, the angle being switched in synchronisation with the sub-hologram update rate of the EASLM. More preferably, the light source comprises an array of light sources disposed between a baffle/shutter array

According to a second aspect of the present invention there is provided a method of displaying a hologram, the method comprising:

successively driving an Electrically Addressable Spatial Light Modulator (EASLM) with a set of sub-holograms which together correspond to a holographic image;

directing coherent light onto the EASLM; and

guiding light output from the EASLM such that the sub-holograms are displayed successively in respective tiled regions of an EASLM projection surface.

According to a third aspect of the present invention there is provided a holographic display comprising:

a light source;

an Electrically Addressable Spatial Light Modulator (EASLM) in the path of the light source and arranged in use to be driven successively by a set of sub-holograms which together correspond to a holographic image;

light guiding means arranged to guide light output from the EASLM such that the sub-holograms are displayed successively in respective tiled regions of an EASLM projection surface; and

an array of lenses disposed on the output side of said EASLM projection plane, the lenses of the array being aligned with respective tiled regions.

For a better understanding of the present invention and in order to show how the same may be carried into effect reference will now be made, by way of example, the accompanying drawings, in which:

Figure 1 illustrates an Active Tiling™ holographic display system;

Figure 2 illustrates EASLM images formed at an EASLM projection surface by illuminating the EASLM with coherent light;

Figure 3 illustrates EASLM images formed at an EASLM projection surface by illuminating the EASLM with coherent light but where light is redirected at the EASLM projection surface by a microlens array;

Figure 4 illustrates EASLM images formed at an EASLM projection surface by illuminating the EASLM with coherent light but where light is redirected at the EASLM projection surface by a holographic redirecting element;

Figure 5 illustrates schematically an EASLM illumination process;

Figure 6 illustrates schematically an alternative EASLM illumination process;

Figure 7 illustrates schematically a portion of an output section of a conventional holographic display; and

Figure 8 illustrates schematically a portion of an output section of an improved holographic display.

There is illustrated schematically in Figure 2 an Active Tiling™ holographic display which comprises an Electrically Addressable Spatial Light Modulator (EASLM) arranged to receive holographic image data from a computer (not shown). The EASLM may be for example an acousto-optic modulator which is sub-divided into a matrix of modulation elements or an array of liquid crystal elements.

The image data received from the computer comprises a series of sub-holograms or hogels (e.g. parts of a larger hologram, holographic stereograms, or phase added stereograms) each consisting of a matrix of light modulation data: when tiled together, these matrices provide a complete data array defining a hologram. The sub-hologram matrices are passed to the EASLM in a raster-scan like sequence, i.e. row by row. The sub-holographic matrices are mapped in turn to the EASLM modulation elements, with the data (or rather a corresponding voltage) at each matrix point being assigned to a corresponding modulation element. A beam of coherent light, provided as described below, is directed onto the surface of the EASLM. Light reflected from the EASLM is modulated by an amount determined by the voltage applied to the modulation element through which it passes.

Light reflected from the EASLM is directed towards a light guiding system. The light guiding system comprises a first large lens followed by an array of light directing lenses. Disposed in front of the lense array is an array of electronically controlled shutters. The shutter array is aligned with the lens array and is controlled by control signals received from the computer which generates the holographic image data. The control signals are synchronised with the image data provided by the computer to the EASLM, such that only one shutter is open at any one time. In addition, each shutter is open for approximately the duration for which a sub-hologram image is present on the EASLM. The shutters are opened in a raster scan sequence, from left to right and row by row.

Each lens of the lens array is arranged to guide light, transmitted through the shutter with which it is aligned, to a corresponding region (referred to as a "tile") of an EASLM projection surface (in this example, the virtual surface is a planar surface although it could be, for example, spherical or cylindrical). The result of the synchronisation between the switching of the EASLM between sub-holograms, and the opening of the shutters of the array, is that each sub-hologram is projected in turn onto the corresponding tile of the projection surface.

It is well known that the human eye and brain remember an image for a short time after that image has ceased to exist, providing that the intensity of the image is sufficiently great. The greater the intensity of the image, the longer the memory. The display device described here takes advantage of this perceptual memory by displaying a single tile of the projection surface for a time which is less than the total time which it takes to scan the entire hologram. That is to say that at any given time during the scanning process, only a fraction of the tiles may actually be presenting an image. At the end of a frame scan, the eye will perceive the complete image frame, even though only a fraction of the tiles making up that frame are actually displayed at any one time. The OASLM of the prior art (see Figure 1) becomes unnecessary.

From Figure 2 it will be appreciated that when the EASLM is illuminated with coherent light and images of coherently illuminated sub-holograms appear at the EASLM

projection surface (where the OASLM would have been). The disadvantage of using coherent light however is that greater care is needed over the direction of the illumination – although images of the EASLM appear in the correct positions, it is as though they are illuminated from the wrong angle.

This effect can be corrected by including additional optics in the system. Ray tracing shows that the necessary optic can be a second lens array placed at the projection plane of the EASLM images (Figure 3). Alternatively, a diffractive or holographic element can be used in place of the microlenses (Figure 4).

In order to ensure the correct functioning of the display, it is necessary that, for each sub-hologram, the EASLM 1 be illuminated by coherent light at the correct angle. This requires different angles for different sub-holograms. Noting that an intermediate image of the desired 3D object produced by each hogel occurs within the display, the following possibilities will be appreciated.

1) Light contributing to the d.c. spot and conjugate image in this plane can be blocked in the intermediate image plane. This minimises the amount of light passing through the remainder of the system, reducing glare. There is also a significant amount of free space for wires, connectors, etc associated with a shutter array.

2) By exploiting a symmetric lens array (or equivalent holographic redirector), locating a point source at the d.c. spot position for one lens should provide plane wave illumination of the EASLM at the correct angle for the image that passes through the opposite lens. The point source could be provided by a semiconductor laser or optical fibre/waveguide. This yields a potentially compact system.

3) By switching off light sources when they are not required, the amount of unwanted light passing through the system is reduced, again minimising glare. Shutters may still be required to eliminate the higher diffracted orders reflected from the EASLM if they aren't considered weak enough to be insignificant. This will largely depend on the structure of the EASLM pixels.

Figure 5 illustrates one suitable illumination system where an array of coherent light sources are provided in the plane of the shutter array. Figure 6 illustrates an alternative system which utilises an external plane wave although it is expected that this would be less efficient.

EASLM image magnification to provide the output display can be achieved by providing an output lens in front of the EASLM projection plane, the lens having an appropriate focal length. Replay optics downstream from the EASLM images can be the same as for a conventional system except that no provision need be made for providing 'OASLM read light illumination'. Alternatively, of course, the second lens array could be used to focus down an externally derived plane wave to give point sources although this would be a less desirable method (see Figure 6).

If the EASLM 1 is operated in transmission then illumination from the appropriate angles may be achieved by multiple sources or by some switchable optics. It may be beneficial to illuminate the EASLM with a non-plane wave although this is yet to be explored. For example, a converging wave may enable an EASLM with smaller pixels (larger diffraction angle) to be used whilst avoiding vignetting (light rays from regions on the EASLM 1 away from the centre not passing through the replicating optics). Converging wave illumination may be achieved simply by moving the point sources in a direction away from the EASLM.

It is noted that the embodiments described here are particularly suited to holograms composed of "hogels" (a type of sub-hologram). Hogels are described in the article "Holographic Bandwidth Compression Using Spatial Subsampling", M. Lucente, Optical Engineering, Vol. 35, No.6, June 1996. The use of hogels takes into account the finite resolution of the human eye to minimise the information content of the computer generated hologram (resulting in a lower resolution image). Hogels offer a method of computation which is potentially fast.

In essence, each hogel can be envisaged as diffracting beams of light into a number of directions. For each direction there is a corresponding fringe pattern that can be obtained from a look-up table. The brightness of beams in any direction (or indeed

whether there is a beam at all) is determined by whether the beam passes through a point on the 3D object and the brightness of the object at that point. The hogel to be displayed is the linear summation of all these fringe patterns, appropriately weighted to provide the required intensity in the image. The resolution of the image is approximately determined by the hogel size, so an attempt is made to match this size to the resolution of the viewer's eyes. This resolution matching is where minimisation of the computation time is expected to be achieved. Figure 2 illustrates the hogel 3D display principle.

One of the features of the hogel method is that, whilst each hogel needs to be illuminated with coherent light, the hogels can be incoherent with respect to each other. For the purpose of this discussion, the term discrete coherence (not to be confused with partial coherence) will be used to describe this. It is expected that such a discrete coherent display system would have reduced speckle in the image.

It is recognised here that a modified Active Tiling™ system could be particularly suited to provide discrete coherently illuminated hogels. The concept used is that the hogels are illuminated with coherent light, time sequentially, so that at any one time, the eye receives light from only one hogel. The 3D image is built up in the eye as it integrates the light contributions from all the hogels over time. This is an incoherent process. The tiling process of the Active Tiling™ system is, of course, time sequential. The speed of the time sequential illumination would need to be faster than the image latency of the eye (e.g. video frame rates).

It is expected that the hogel images do not need to be perfectly 'butted' together, relaxing optical design constraints. Deliberately overlapping hogels may allow some modification of the image quality (perhaps reducing the perception of hogel boundaries) although this would effectively require a greater number of pixels in the overall display.

The discrete coherent nature of the sub-holograms (and in particular of hogels) means that sub-hologram images can be tiled with individual optics, reducing the need for extra large elements. Figure 7 Schematic illustrates conventional replay optics where a single large lens (only the lower portion of the lens is shown in the Figure) is positioned

in front of the EASLM projection surface. Figure 8 illustrates how the use of tilted EASLM image 'planes' reduces the angle through which the replay optics have to direct the light. This allows the use of thinner, smaller optics.

It will be appreciated by the person of skill in the art that various modifications may be made to the above described embodiments without departing from the scope of the present invention. For example, the device described above may provide a single channel of a multi-channel holographic display. That is to say that a number of display devices may be arranged in an array such that the output provides a single hologram.

Claims

1. A holographic display comprising:

a source of coherent light;

an Electrically Addressable Spatial Light Modulator (EASLM) in the path of the light source and arranged in use to be driven successively by a set of sub-holograms which together correspond to a holographic image; and

light guiding means arranged to guide light output from the EASLM such that the sub-holograms are displayed successively in respective tiled regions of an EASLM projection surface.

2. A display according to claim 1, wherein said light guiding means comprises replicating optics arranged in use to replicate the light output from the EASLM so as to provide multiple images.

3. A display according to claim 2, wherein the light guiding means comprises an array of electronically controlled shutters disposed between the replicating optics and said EASLM projection surface, said shutters being controlled such that only that shutter, which is aligned with a tiled region of the EASLM projection surface associated with a given sub-hologram, is open when the EASLM is being driven by that sub-hologram.

4. A display according to any one of the preceding claims, wherein the light guiding means comprises means disposed at the EASLM projection surface, or between the EASLM and the EASLM projection surface, for causing the apparent diverging light illumination of the EASLM images to be redirected to appear to be a plane wave or other wavefront illumination.

5. A display according to claim 4, wherein said means causing diverging light to be redirected to provide an apparent wavefront illumination comprises an array of lenses or a holographic redirector disposed at or near the EASLM projection surface.

6. A display according to any one of the preceding claims, wherein the light source used to illuminate the EASLM may comprise a single light source, or a plurality of light sources.

7. A display according to claim 6, wherein the angle of incidence of the light upon the EASLM depends upon the spatial position, within the hologram, of a sub-hologram currently being displayed, the angle being switched in synchronisation with the sub-hologram update rate of the EASLM.

8. A display according to claim 6 or 7, wherein the light source comprises an array of light sources disposed behind the replicating optics.

9. A display according to any one of the preceding claims, wherein baffles are positioned in an intermediate image plane so that light associated with the d.c. spot and conjugate image is blocked.

10. A method of displaying a hologram, the method comprising:

successively driving an Electrically Addressable Spatial Light Modulator (EASLM) with a set of sub-holograms which together correspond to a holographic image;

directing coherent light onto the EASLM; and

guiding light output from the EASLM such that the sub-holograms are displayed successively in respective tiled regions of an EASLM projection surface.

11. A holographic display comprising:

a light source;

an Electrically Addressable Spatial Light Modulator (EASLM) in the path of the light source and arranged in use to be driven successively by a set of sub-holograms which together correspond to a holographic image;

light guiding means arranged to guide light output from thc EASLM such that the sub-holograms are displayed successively in respective tiled regions of an EASLM projection surface; and

an array of lenses disposed on the output side of said EASLM projection plane, the lenses of the array being aligned with respective tiled regions.

12. A holographic display comprising a plurality of displays according to claim 11, the displays being combined to enable a holographic image to be displayed with a large number of pixels.

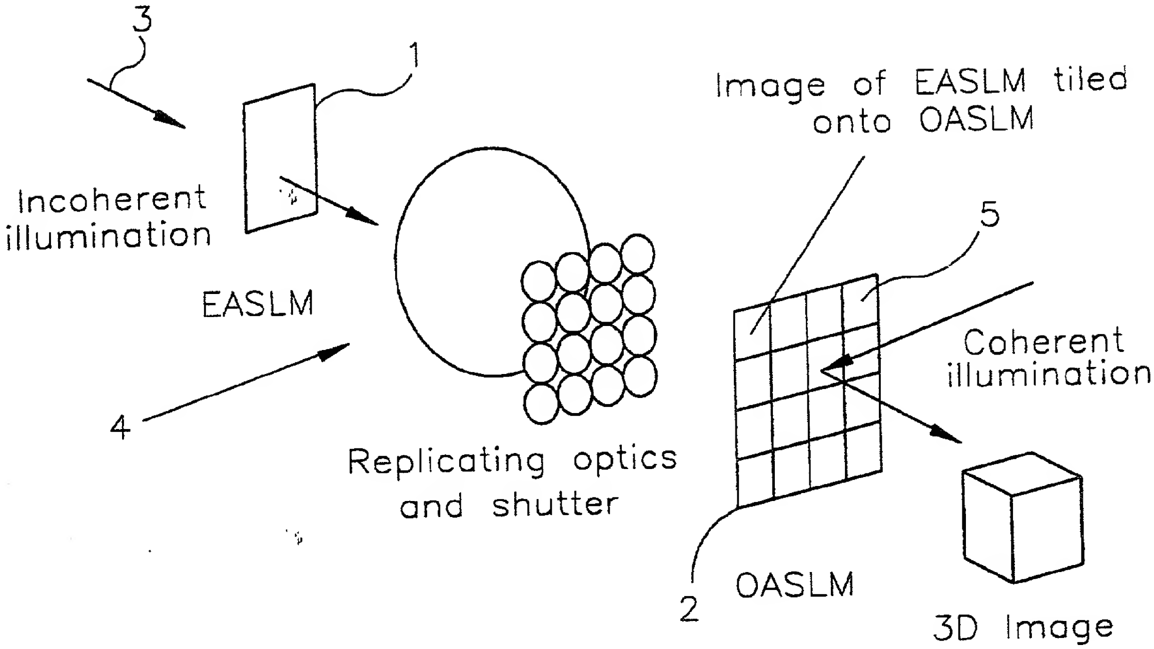
3
1
Image of EASLM tiled onto OASLM
Incoherent illumination
5
EASLM
Coherent illumination
4
Replicating optics and shutter
2
OASLM
3D Image

FIG 1

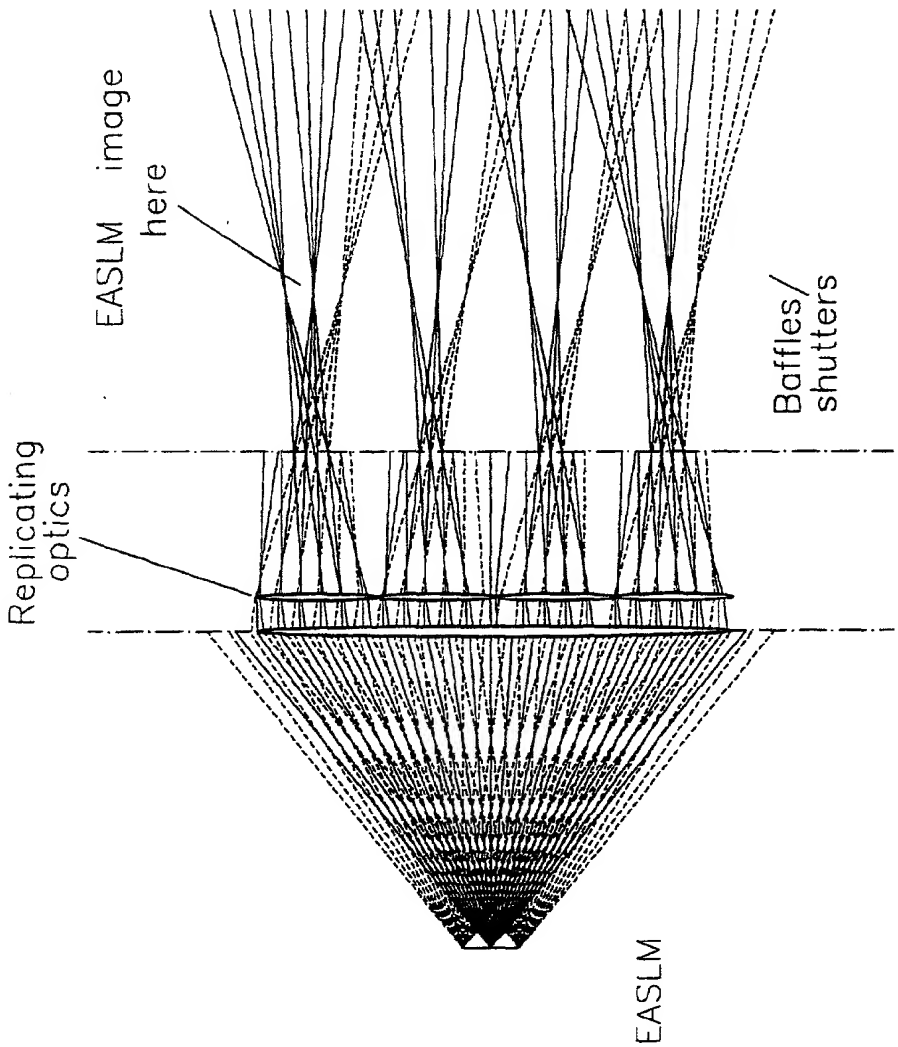
EASLM image here
Baffles/ shutters
Replicating optics
EASLM

FIG 2

09/926734



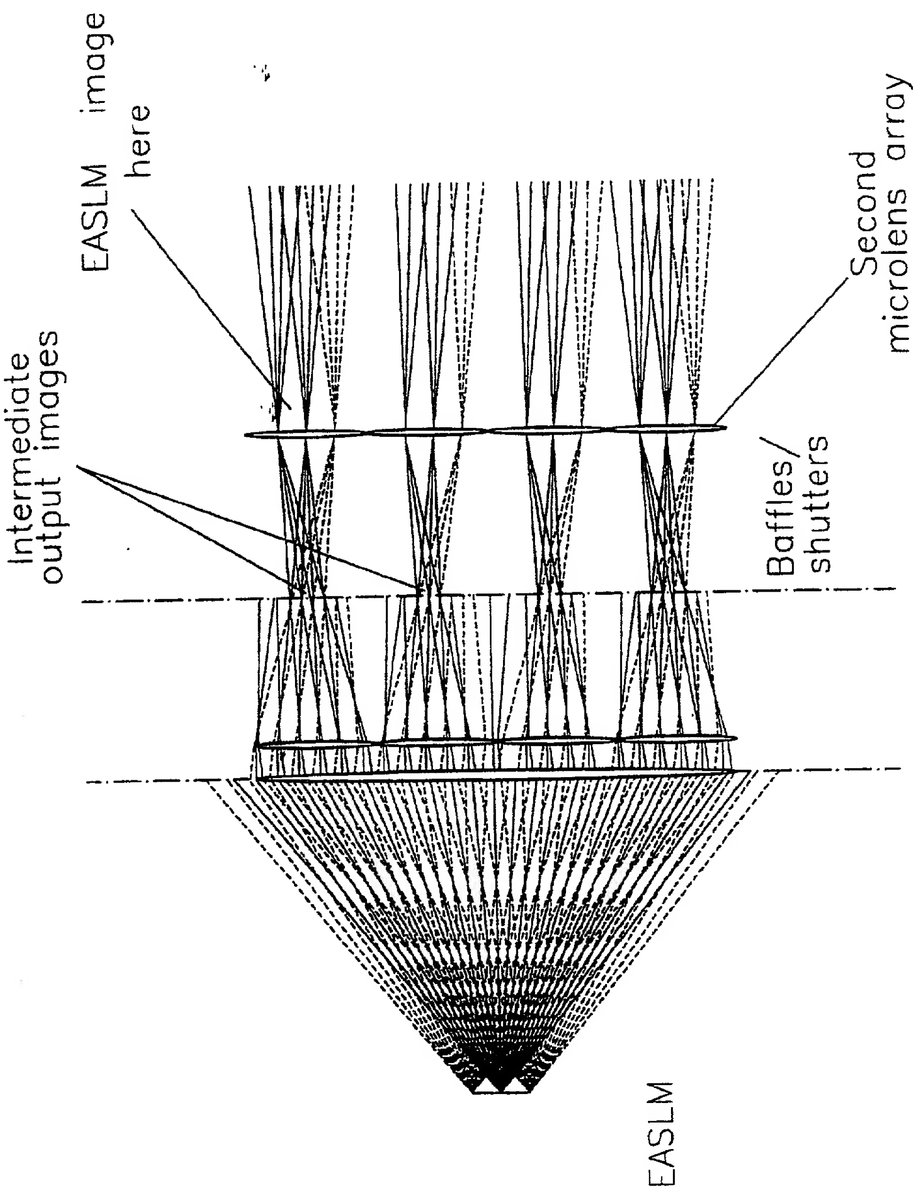


FIG 3

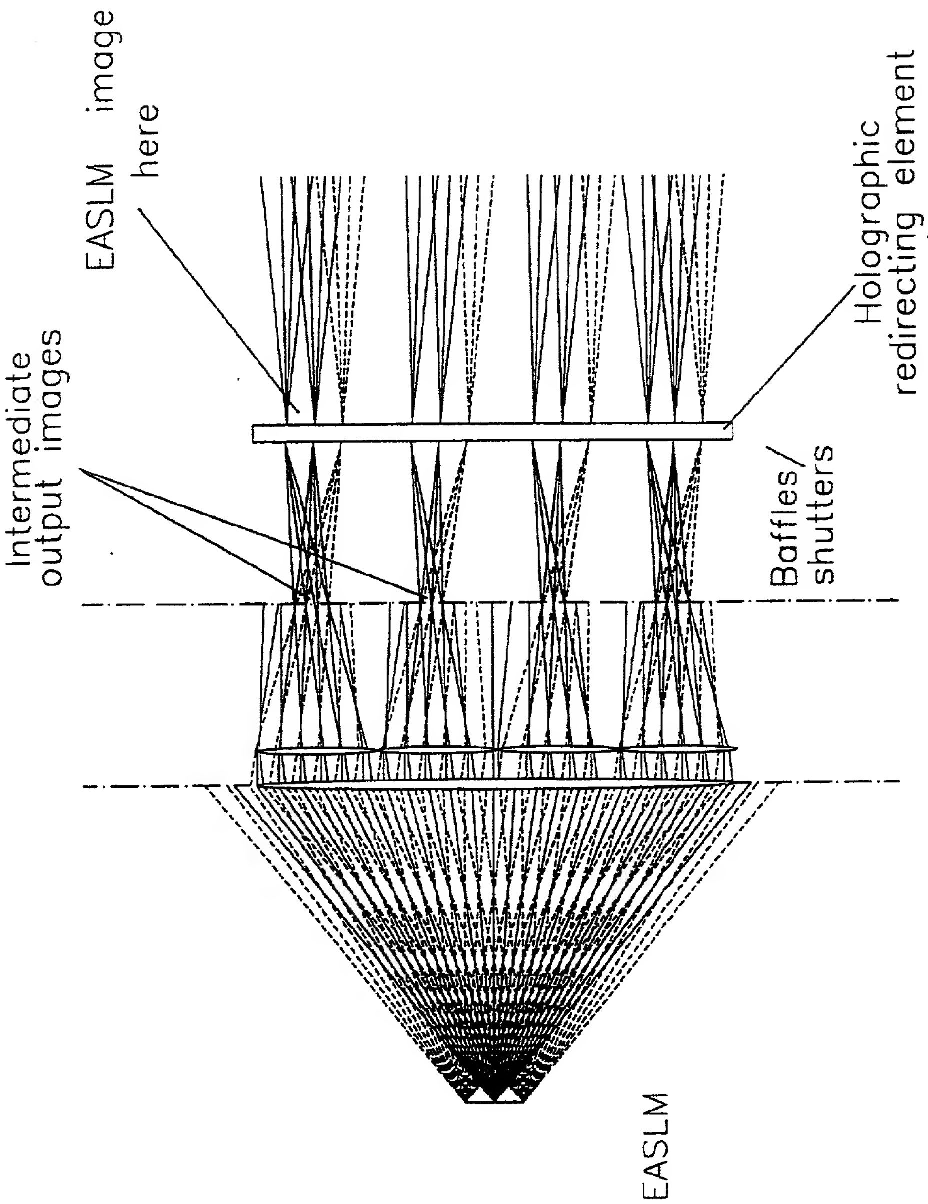
EASLM image here
Intermediate output images
Holographic redirecting element
Baffles/ shutters
EASLM

FIG 4

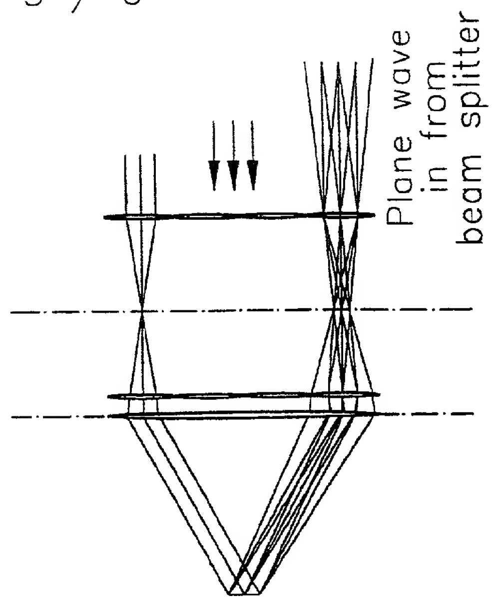
Plane wave
in from
beam splitter

FIG 6

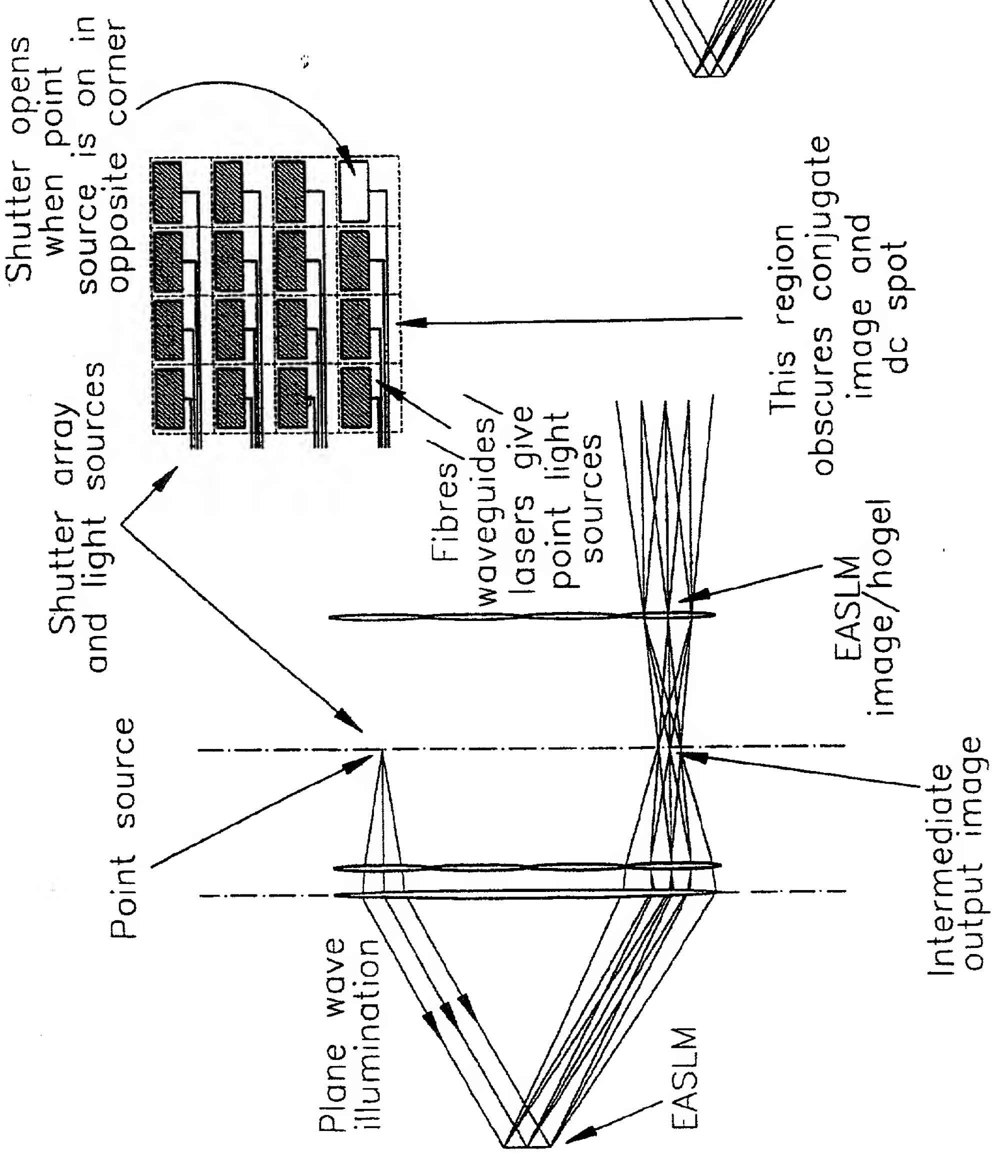
Shutter opens
when point
source is on in
opposite corner
Shutter array
and light sources
Point source
Plane wave
illumination
EASLM
Fibres/
waveguides/
lasers give
point light
sources
This region
obscures conjugate
image and
dc spot
EASLM
image/hogel
Intermediate
output image

FIG 5

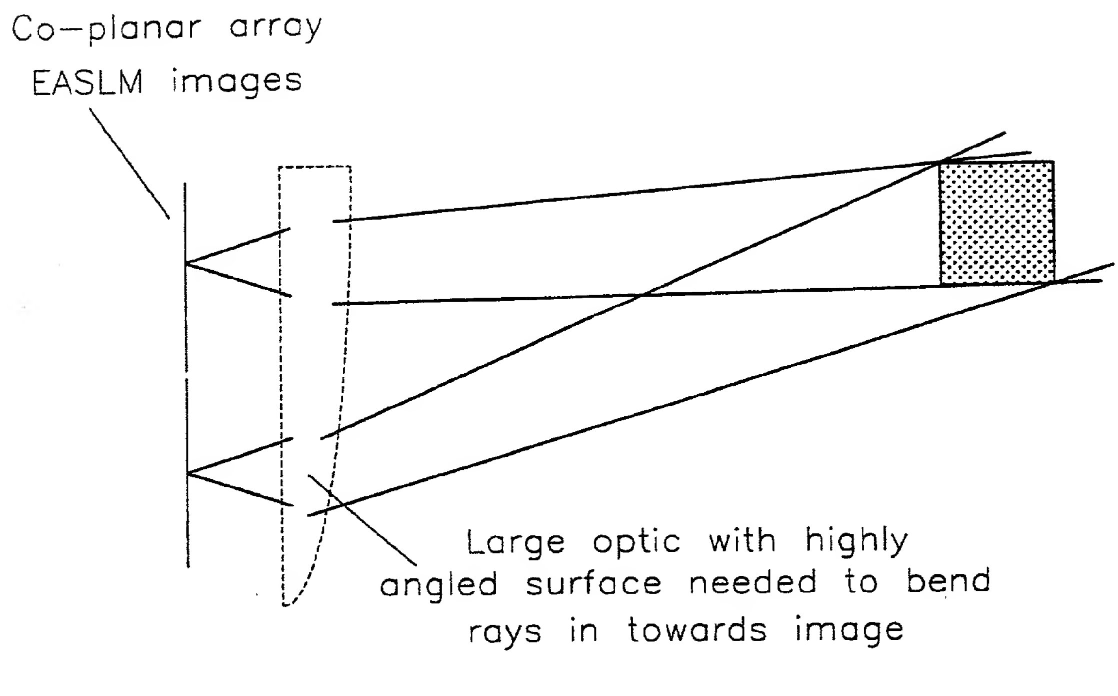
Co-planar array
EASLM images
Large optic with highly
angled surface needed to bend
rays in towards image

FIG 7

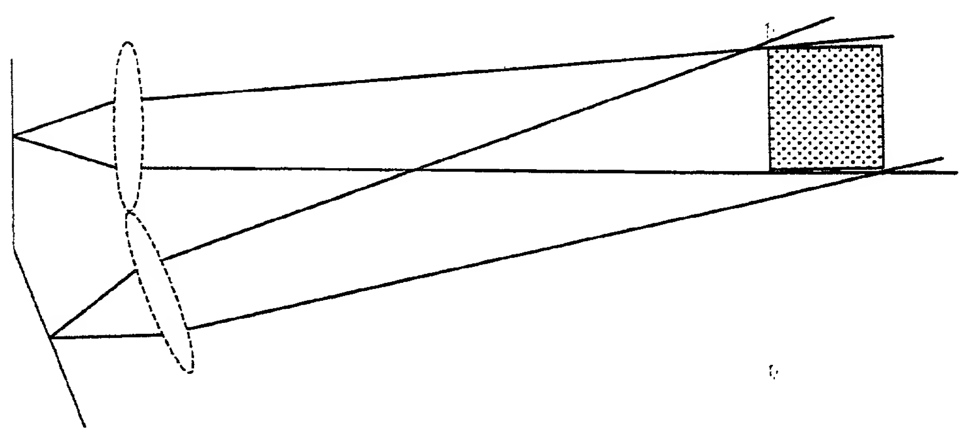

FIG 8

Docket No. 108347-00014 ARENT FOX KINTNER PLOTKIN & KAHN, PLLC

# Declaration For U.S. Patent Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled
(Insert Title) HOLOGRAPHIC DISPLAYS

the specification of which is attached hereto unless the following box is checked:

| | | | | |
|---|---|---|---|---|
| ☒ | was filed on May 18, 2000 | | | As PCT International Application |
| | Number PCT/GB00/01903 | and was amended on | | |
| And/or | was filed on December 10, 2001 | | | As United States Application |
| | Number 09/926,734 | and was amended on | | |

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. '1.56.

I hereby claim foreign priority benefits under 35 U.S.C. '119(a)-(d) or '365(b) of any foreign application(s) for patent or inventor's certificate, or '365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate or PCT International Application having a filing date before that of the application(s) for which priority is claimed:

| (List prior foreign applications) (Number) | (Country) | (Day/Month/Year Filed) | Priority Claimed |
|---|---|---|---|
| 9913432.2 | United Kingdom | 09/06/99 | ☒ Yes ☐ No |
| | | | ☐ Yes ☐ No |
| | | | ☐ Yes ☐ No |

I hereby claim the benefit under 35 U.S.C. '119(e) of any United States provisional application(s) listed below.

| (Application Number) | (Filing Date) |
|---|---|
| | |
| | |

☐ See attached list for additional prior foreign or provisional applications.

I hereby claim the benefit under 35 U.S.C. '120 of any United States application(s) or '365(c) of any PCT International application(s) designating the United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) (U.S. or PCT) in the manner provided by the first paragraph of 35, U.S.C. '112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. '1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

| (List prior U.S. Applications or PCT International applications designating the U.S.) (Application Serial No.) | (Filing Date) | (Status) (patented, pending, abandoned) |
|---|---|---|
| PCT/GB00/01903 | May 18, 2000 | Pending |
| | | |

And I hereby appoint the firm of Arent Fox, Customer Number **004372** including as principal attorneys: Robert B. Murray, Reg. No. 22,980; Charles M. Marmelstein, Reg. No. 25,895; George E. Oram, Jr., Reg. No. 27,931; Douglas H. Goldhush, Reg. No. 33,125; Richard J. Berman, Reg. No. 39,107; Murat Ozgu, Reg. No. 44,275; Robert K. Carpenter, Reg. No. 34,794; Gregory B. Kang, Reg. No. 45,273; Rustan Hill, Reg. No. 37,351; Kevin Turner, Reg. No. 43,437; Hans J. Crosby, Reg. No. 44,634; Rhonda L. Barton, Reg. No. 47,271; Sam Huang, Reg. No. 48,430; Lynn A. Bristol, Reg. ~~No. P48,898~~; Brian A. Tollefson, Reg. No. 46,338, Lynne D. Anderson, Reg. No. 46,412; D. Daniel Dzara, II, Reg. No. 47,543, Laurence J. Edson, Reg. No. 44,666; Michael A. Steinberg, Reg. No. 43,160; Dinnatia J. Doster, Reg. No. 45,268; and Jonathan A. Kidney, Reg. No. 46,195.

Please direct all communications to the following address: ARENT FOX KINTNER ~~PLOTKIN & KAHN, PLL~~C
1050 Connecticut Avenue, N.W., Suite 400
Washington, D.C. 20036-5339
Telephone No. (202) 857-6000; Facsimile No. (202) 638-4810

The undersigned hereby authorizes the U.S. attorneys named herein to accept and follow instructions from the undersigned's assignee, if any, and/or, if the undersigned is not a resident of the United States, the undersigned's domestic attorney, patent attorney or patent agent, as to any action to be take in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorneys and the undersigned. In the event of a change in the person(s) from whom instructions may be taken, the U.S. attorneys named herein will be so notified by the undersigned.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor Douglas PAYNE

Inventor's signature D A Payne 8th March 2002
Date

Residence Worcestershire, WR14 3PS, United Kingdom GB

Citizenship British

Post Office Address Qinetiq Limited, St. Andrews Road, Malvern, Worcestershire WR14 3PS, United Kingdom

Full name of second inventor ~~Christopher W. SLINGER~~

Inventor's signature W Slinger 13 March 2002
Date

Residence Worcestershire WR14 3PS, United Kingdom GBX

Citizenship British

Post Office Address Qinetiq Limited, St. Andrews Road, Malvern, Worcestershire WR14 3PS, United Kingdom

JW

Full name of third inventor

Inventor's signature
Date

Residence

Citizenship

Post Office Address

Full name of fourth inventor

Inventor's signature
Date

Residence

Citizenship

Post Office Address

Full name of fifth inventor

Inventor's signature
Date

Residence

Citizenship

Post Office Address

Full name of sixth inventor

Inventor's signature
Date

Residence

Citizenship

Post Office Address

Full name of seventh inventor

Inventor's signature
Date

Residence

Citizenship

Post Office Address

Full name of eighth inventor

Inventor's signature
Date

Residence

Citizenship

Post Office Address

Full name of ninth inventor

Inventor's signature
Date

Residence

Citizenship

Post Office Address